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ICT COMPETENCES FOR TEACHERS IN 21ST CENTURY – A DESIGN FRAMEWORK FOR SCIENCE PRIMARY TEACHER EDUCATION COURSES

Abstract

One of the challenges higher education institutions face is to effectively endow science primary teachers with competences on "how", "where", "when" and "whether" to use technological resources (software and hardware) in teaching contexts. Teachers' Technological Pedagogical Content Knowledge (TPCK) requires knowing about how to represent subject matter (i.e. sciences) with technology from a socio-constructivist approach. A qualitative methodology following a design-based-approach is adopted in this study with the intention to develop a design framework of technology enhanced science education for the professional development of primary teachers. The study identifies strategies for TPCK development of science primary teachers, particularly in higher education (under and postgraduation courses). The paper presents some of the results of the study, which suggest that the combination of problem-based approaches (pedagogy) with research-based technological resources (technology) could be a way to develop innovative science lessons for pupils.

Keywords: science education, teacher education, teaching and learning of sciences, technological pedagogical content knowledge

Introduction

Primary science aims to develop scientific process skills, foster the acquisition of science and technological concepts, and develop particular attitudes in children. The integration of technological resources in primary sciences could facilitate the promotion of pupils' active participation in inquiry activities (Warwick, Wilson & Winterbottom, 2006). Consequently, primary teachers should understand the representation of science concepts using technologies, as well as pedagogical strategies that use ICT in order to improve pupils' learning (Murphy, 2003; Warwick, et al., 2006).

Technological and pedagogical content knowledge (TPCK) should be the basis of effective teaching with technology. TPCK refers to the knowledge required by primary teachers to integrate technological resources in their teaching area (i.e. sciences) (Koehler & Mishra, 2009). Primary teachers should understand the representation of science concepts using technologies, as well as pedagogical strategies that use ICT in order to improve pupils' learning (Graham et al., 2010). Science teachers' TPCK requires knowing about how to represent subject matter (sciences) with technology from a socio-constructivist approach (Jimoyiannis, 2010a, 2010b). TPCK represents the articulation between pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK) and technological content knowledge (TCK) of (science) teachers (Ferdig, 2006; Jimoyiannis, 2010b; Koehler & Mishra, 2009).

However, the use of technological resources by science (primary) teachers in teaching contexts has been irregular. The constraints are: the nature of the science curriculum, which does not include the potentialities of ICT; the lack of technological resources available in schools; and teachers' technophobic attitudes (Juuti, Lavonen, Aksela & Meisalo, 2009; Moreira, Loureiro & Marques, 2005). In this context, it is vital to conduct research in order to identify how this more integrated approach supports the development of TPCK in science primary teachers. In order to contribute towards the development of Teachers' PCK, Alarcão (1994) suggests the development of synergies in the three dimensions of the curricular areas related with "Teaching Methodologies": research (that studies the problems related to the teaching and learning process of different subjects); professional (related to the teachers in action) and curricular (related to the formative dimension of Teaching Methodologies in teacher education courses). Based on this perspective, it is vital to improve the articulation between Learning/Technology/Interaction in teacher education courses (Moreira & Loureiro, 2008). This articulation can improve the relationships between students and teacher-trainers, and between them and the learning content and the technological resources, so as to achieve improved students' learning outcomes.

Research methodology

A design-based research (DBR) approach was adopted in order to identify which "guidelines" might contribute towards the development of science primary teachers' TPCK in a science teaching context and how these guidelines should be integrated in the design of a science teacher education course (initial and in-service). DBR projects could offer new educational knowledge to act (teach, learn, and design educational innovations) more intelligently.

The features of a DBR approach are: designing is an iterative process; designing generates an artefact that is applicable to a wider audience than just the correspondence group; and designing renders novel educational knowledge about science teaching and learning. The artefact could be a technological resource, a teacher guide or a synopsis of a teaching sequence (Andriessen, 2007; Collective, 2003; Juuti & Lavonen, 2006).

In this study, the artefact is a framework with "guidelines" that could contribute towards the development of teachers' TPCK in science teaching contexts. The study was divided in two phases:

- **First phase**: aims to understand how to promote science primary teachers' understanding of the multiple technological resources available, and how those technological resources can be used to enhance a wide variety of sciences teaching activities. This phase has two data collection tasks:

- *First task* (January 2009 to October 2009): 20 curriculum plans related to Educational Technology (ET) (i.e. "ICT in education") were analysed from an exploratory point of view. Data were obtained from "Basic Education" degrees (1st Bologna cycle), offered by Portuguese public higher education institutions (7 universities and 13 polytechnic schools).
- *Second task* (November 2009): 4 National educational technology researchers were interviewed. The researchers were specialized in the development of teacher education courses (undergraduate and postgraduate

degrees) (ReA, ReB, ReC) and one of them was also an expert in science education research (ReD). The semi-structured interview had predefined open questions, but the interviewer used further questions during the interaction with the researchers.

- **Second phase**: aims to develop, implement and evaluate the effectiveness and mid-term impact of the in-service science teacher education course in TPCK development. This phase has two data collection tasks:

- *First task* (December 2009 to July 2010): participant observation performed by the researcher during the development and implementation of the in-service Science Primary Teacher Education Course.
- Optimal guidelines that emerged from the first phase were put into practice in the curricular areas of "Sciences Teaching Methodologies" and "ICT in Science Education" of the University of Aveiro Master's degree in Science Education (2nd Bologna cycle) in Portugal. This Master's degree was specifically designed for in-service science primary teachers who want to develop/improve their professional knowledge related to science teaching and learning practices.
- The participants in this phase were the researcher, two teacher-trainers and nine in-service science primary teachers. Teacher-trainers were asked to participate in this project, based on their formative and research interests, as well as the interest of the development of TPCK of in-service science teachers of the Master's degree in Science Education.
- *Second task* (July 2010 to May 2011): data was collected through interviews performed by the researcher of this study to nine in-service science teachers and two teacher-trainers of those curricular areas, who participated in the project. Specifically, it was important to assess if the strategies and technology-rich activities adopted in the curricular areas of "Sciences Teaching Methodologies" and "ICT in Science Education" developed and/or improved in-service science primary teachers' TPCK, particularly: to reflect about their own professional practices; incorporate research outcomes in their sciences teaching and learning activities; expand pedagogical innovations in the classroom within the educational community.

A content analysis approach was adopted in order: to identify the technological resources that could be articulated with the sciences teaching and learning process (TCK); to understand which ICT competences should be developed in science primary teacher education courses (under and post graduation degrees) (TPK); to define teaching and learning strategies that could be adopted to develop and assess students' learning (PCK).

Results and Discussion

These results show that there are three critical elements for the development of science teachers' TPCK: 1) knowledge of science; 2) knowledge of science pedagogy; 3) knowledge of technology. Therefore, it is essential to develop synergies in the three dimensions of Teaching Methodologies: research, professional and curricular. At the research level, science primary teachers should be asked to conduct research projects about educational problems related to sciences teaching and/or learning processes. At the professional level, curricular areas of "Sciences

Teaching Methodologies" and "ICT in Science Education" should be articulated with professional practices of the in-service science primary teachers. At the curricular level, the formative dimension of teaching perspectives should allow developing TPCK in science (i.e. combining science, technology and societal subjects (content), with inquiry learning and problem-based learning methods (pedagogy) with research-based technological resources (technology). For instance, in-service science primary teachers explore how Web 2.0 tools can be used to enhance a wide variety of activities in science teaching and learning including:

- Ning: enhancing social networking between in-service science primary teachers and their teacher-trainees (e.g., ticedidacticadasciencias.ning.com);
- Box.net: enabling the sharing of videos, audio/podcasts and scientific literature about research studies that endorse the integration of ICT-based research tools in science teaching and learning, etc. (e.g., www.box.net);
- MindMeister: enhancing collaborative mind-mapping in order to understand the representation of scientific and technological concepts using technologies (e.g., www.mindmeister.com/pt);
- WordPress: blogging tool that enables the development of digital portfolios to give in-service science primary teachers the opportunity to take on a self-regulating role over their learning process (e.g., wordpress.com).

At the beginning of the course, all in-service science primary teachers lacked confidence with integrating Web 2.0 tools in their science classrooms. However, once they acquired the critical skills in their use, they were able to use the tools innovatively in their classrooms. They were provided with opportunities to implement small research projects in their science classroom contexts (Guerra, 2010). We will present two research projects implemented by two in-service science primary teachers: a senior and a junior professional.

Teacher A – senior professional

Teacher A teaches pupils aged 6 and 7 at a public science school in the north of Portugal. She has 15 years of teaching experience but little digital competence in the integration of Web 2.0 tools in the teaching and learning process. During her involvement in the course (from January to July 2010) she explored two innovative and emerging technological tools in authentic science teaching and learning contexts: the WordPress blog 'Cientistas de palmo e meio' (Junior Scientists) – available at cientistasdepalmoemeio.wordpress.com, and the online mind mapping and brainstorming tool, *MindMeister*. She aimed to develop her pupils' ability to find and select information about current scientific and technological issues. The activities she designed have a science, technology and society orientation with the long-term aim of developing pupils' scientific literacy. The blog was used to: involve the pupils' parents in the teaching process, so that they could participate in their learning development; improve pupils' digital competencies (i.e. effective communication); disseminate pupils' work within and outside the classroom, including sharing and collaborating with other schools. The teacher chose the MindMeister tool to enable pupils to represent science concepts. Although this teacher was initially very reluctant to use Web 2.0 tools, since attending the course not only did she carry out the research, but also started collaborating with another

science teacher in a blog called Inquisitive Kids, available at pequenoscuriosos. wordpress.com.

Teacher B – junior professional

Teacher B has less than two years of teaching experience. She teaches pupils aged 6 to 10 and is doing a PhD in Education at the University of Aveiro. While attending the doctoral program she designed a technology-based science activity and explored a Web 2.0 tool that allowed sharing online photos using Flickr (www.flickr.com/photos/projectolandscape). Her aims were to develop pupils' understanding about science and technology aspects of the landscape of Aveiro. Pupils took photographs of the city of Aveiro and analysed the role of physical and natural landscapes using the photographic evidence. The photographs were placed by the pupils on the Flickr platform, which served, simultaneously, as storage for photographs and for promoting analysis, discussion and reflection by pupils about environmental aspects of Aveiro, such as the water quality of its lagoon.

Conclusions

The study identifies strategies for TPCK development of science teachers, particularly in higher education courses. In these contexts, curricular areas should be designed drawing attention to three main aspects: 1) TPK, TCK and PCK are key elements for developing science teachers' TPCK in science; 2) All curricular areas of science teacher education courses (1st, 2nd and 3rd Bologna Cycles) should contribute for science teachers' TPCK development; 3) The curricular area of teaching methodologies (i.e. didactics of sciences) has a crucial role in the science teachers' TPCK in science development.

A framework for science teacher education courses should enhance the synergies between research, professional and curricular dimensions. At the research level, science primary teachers should be asked to conduct research projects about educational problems related to sciences teaching and learning processes. At the professional level, curricular subjects should be articulated with professional practices of the science teachers. At the curricular level, the formative dimension of sciences teaching perspectives should allow to combine STS subjects (content) with inquiry learning and problem-based learning methods (pedagogy) and with research-based technological resources (technology). The results of this later stage of the study will be the object of future writings.

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